

RISK QUANTIFICATION FOR ENVIRONMENT ELEMENTS ALONG THE TRAFFIC ROUTE

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Research article

Abstract: Currently the environment protection is a frequent topic in scientific groups. Many themes from the environment area exist, which are discussed at conferences and scientific events. One of these topics is surely dangerous substances transport risk assessment for the environment. The following paper describes dangerous substances spreading at the earth surface, the reach of their effect and their impact on single environment elements. The result is a valuation, i.e. expression of value of affected natural environment and its single elements.

Key words: Bandwidth exposure, risk, liquid, biodiversity, biotope.

Introduction

The pressure on risk assessment in many branches of human activities increases at this time more and more. It is also the case of dangerous goods transport. In this paper, we will put mind to risk assessment of dangerous liquids transport on the traffic routes and we will limit only to impacts of possible accidents for the environment along the transport routes.

At the beginning, it is necessary to say that all risk models, which describe real situation in human life, come from general risk model, which can be described by the following formula:

$$R = P \cdot N \quad (1)$$

where R is risk, P event occurring probability, N event consequences.

So, it is reality simplification. There are many parameters for single equations by specific events assessment. These parameters are given by reflected boundary conditions.

Materials and methods

Bandwidth exposure for liquids

The bandwidth assessment of negative effects reach for liquids is more difficult than for gases. There are more scenarios of liquid spread and also wider spectra of potentially threatened environment elements. On the other hand the bandwidth is considerably smaller.

Model principle

The process of liquid spreading is spatially discretized using the square network. The time discretization is realized by time steps calculation. The cut of interest area is divided into square elements in the model by means of square network. The surface of each element is horizontal, homogenous in terms of all its parameters and it presents location whereon the processes are time steps simulated and the liquid balance is done.

The element altitude is primarily determined from altimetry data. In the database ZABAGED there are two types of data, by which the terrain morphology (contour lines and quoted points) is described. If some contour line passes through some element or there is some dimensioned point in this element, the elevation of this contour line or dimensioned point is associated to this element. The elevation for other elements is calculated by specially modified interpolation methods.

The liquid can flow always only to the neighbouring elements with lower surface level. If some lower surface level will be located in more elements, the flow will be divided. If no neighbouring element has lower surface level, then no flow will happen in that time step. It is concerned about element or elements group accordant with local terrain negative elevation which is first filled by liquid and then it may come to the overflow.

The important factor is the liquid capture on the terrain. Important thing is that each element has some small inequalities, which can be filled with the liquid. Also the vegetation cover can much increase specific surface for liquid capture. Both mentioned factors are determined on the basis of GIS data about

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cover type, which is located at each element (Saska et al., 2010). The minimal layer of captured liquid is defined for each surface type with liquid properties deliberation. When the liquid gets into the element, it has to reach this layer first. Only after this the liquid can spread to neighbouring elements.

During liquid flushing on the surface, its infiltration below the surface occurs as well. The liquid soil infiltration is expressed like the liquid decrease in the element per the time step. The evaporation solution is relatively simple. The quantity of evaporated substance per one time step is dependent on the liquid type primarily. We can ignore this process by many substances.

The calculation of liquid volume change in one time step is executed for each element in consequence of running physical processes. It is done by the liquid balance at the end of the time step and the state values are recorded. These values enter into the next time step like initial. Cumulated data about liquid decrease from each element are also monitored (evaporation, infiltration, move to surface waters) (Simmons and Keller, 2003; Simmons and Keller, 2005).

Results

Threatened zone mapping

For the presentation, the road E65 (I/10) between Loužnice and Plavý was chosen. The outflows of 30 m³ of diesel oil in 10 m steps were calculated in this sector. In each of the 10 m interval 3 potential outflow sources are supposed - on both roadsides and in the centre of the road. Totally spreading contours for more than 3000 pools were determined. The calculation was done deterministically with infiltration mean values.

On Fig. 1 there are displayed contours of single pools accordant with spilling of 30 m³ of diesel oil by the accident between Loužnice and Držkov. According to the large density of potential outflow sources these pools are often bordering and overlapping. The background is the orthophotomap completed with contour lines and chosen objects (roads, ways, watercourses, buildings) from topographic map.

Pools are put together into the sheet and displayed against topographic map background (Fig. 2). In the display scale, the difference is not so evident but in terms of next processing, this difference is important. The pools contour on the figure creates coherent polygon. This way created polygon represents the exposure zone caused by liquid outflow by the road transport.

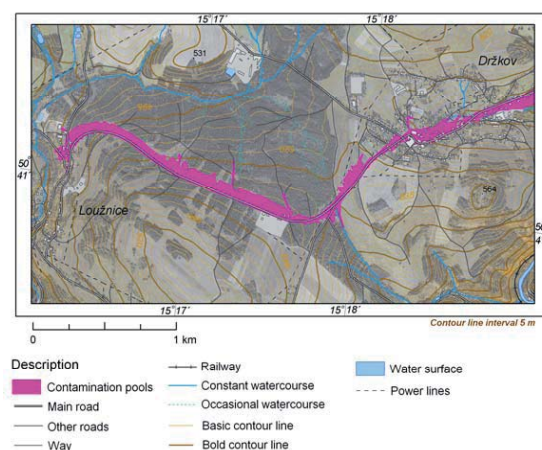


Fig. 1 Single pools incurred by outflow of 30 m³ fuel oil in the segment of the road E65 Loužnice - Držkov

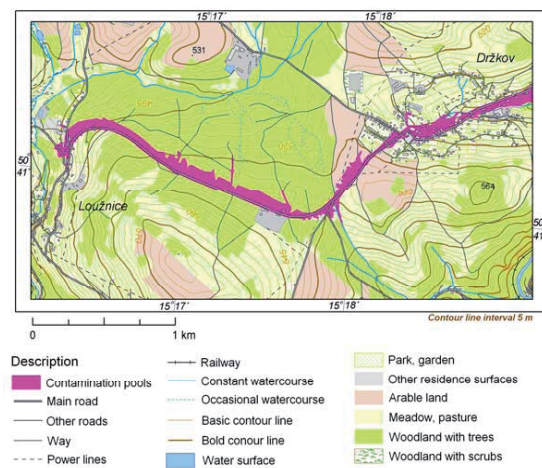


Fig. 2 Threatened zone for the transport of 30 m³ fuel oil in the segment of the road E65 Loužnice - Držkov

On Fig. 3, 3D look on threatened area for sector Držkov - Plavý from south-west is displayed. It is evident how the form of threatened zone is dependent on the terrain morphology.

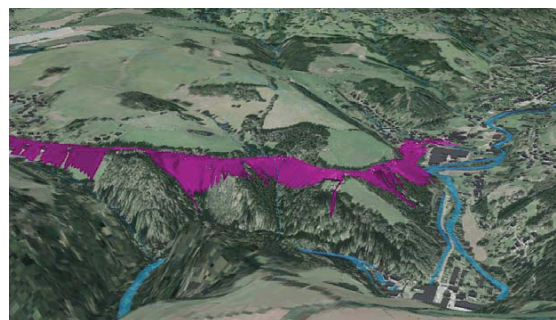


Fig. 3 The look on the threatened zone for the road segment Držkov - Plavý from south-west

The assessment of ecologic damage and social losses of the ecosystems service

The assessment of biotopes biodiversity and their ecosystem services

Biotopes are covered in detail by the Methodology of Czech Republic biotopes evaluation, which was prepared for the Ministry of Environment in 2003 (Seják and Dejmal, 2003). This methodology identifies 192 biotope types in total for the area of the Czech Republic and each square meter of the Czech Republic can be classified like some concrete biotope.

The method is based on expert generation of complete list of biotopes, which occur on the specific area. The catalogue of nature and nature close biotopes NATURA 2000 (Seják et al., 2010) was used in the Czech Republic. This catalogue was supplemented by an interdisciplinary team of ecologists about more anthropic affected biotopes (nature far biotopes, nature foreign biotopes and nature foreign biotopes with limited biota). The point value for each biotope was got based on interdisciplinary cooperation of different specialized ecologists. Expert pointing is based on the evaluation of eight following ecologic characteristics for each biotope. Each characteristic can get point value from one to six points:

1. ***Biotope type maturity*** [points according to phylogenetic age of formation and type],
2. ***Biotope type naturalness*** [6 points completely natural, 1 point completely anthropogenic],
3. ***Diversity of biotope type structure*** [6 point for all vegetation layer],
4. ***Diversity of biotope type species*** [points according to number of all naturally occurring species],
5. ***Biotope type rarity*** [points according to geographic and climatic uniqueness, rate and area],
6. ***Biotope type species rarity*** [points according to number of rare and endangered species],
7. ***Biotope type sensitivity*** (vulnerability) [points according to vulnerability degree due to habitat conditions],
8. ***Biotope type threat*** [points according to dependence on human activities change].

To get the biotope point value, the sum of points from the first four characteristics is multiplied by the sum of points from the second four characteristics and the resulting number is related to maximal possible number of points (576). This calculation formula enables to evaluate and order all biotopes according to their ecologic quality with relevant number of points in the range from three to hundred points.

The point value for each biotope is converted to money by points multiplying with average

social costs of natural structures recovery, so with average national costs of one point. On the basis of representative analysis of 136 revitalizing projects, the point value of 12,36 CZK was quantified in the Czech Republic till 2003. If we valorise the point value by inflation rate in the period of 2003 - 2008, then the value of one point is 14,50 CZK in 2008. So, the value of one point represents the costs for increase of biotope quality using revitalizing measures of 1 point.m⁻².

The complete description of biotopes assessment method in the form of final report electronic book publication is possible to find on the website of Faculty of Environment of Jan Evangelista Purkyně University in Ústí nad Labem <http://fzp.ujep.cz/Projekty/VAV-610-5-01/HodnoceniBiotopuCR.pdf>, brief description of the method with biotopes list then on the website http://fzp.ujep.cz/projekty/bvm/bvm_CZ.pdf.

Biotopes evaluation method sorts systematically all biotopes in the Czech Republic according to their ecological importance as well as specific environment for plants, animals, and microorganisms. Single selected biotopes and values of their examined parameters are shown in Tab. 1.

Risk integration for environment elements along the traffic route

The aim of integration is the evaluation of social risk of environment damage along the traffic route. The procedure of social risk calculation by dangerous liquid transport is methodically shown on Fig. 4. The result is a social risk of transport of one liquid load endangering environment elements. (CPR, 2005; Crowl and Louvar, 1990).

Within the solution, basic accident frequency by dangerous substance transport, separately for gases and liquids, was determined for each traffic route. The integration procedure is as follows:

1. The transport route is divided into segments, best per 10 - 20 meters.
2. For single segments, we determine modified frequencies according to local characteristics (villages, curves, straight segments).
3. We determine the quantity and kind of transported liquid. We expect the instantaneous outflow of the whole quantity and according to this we specify the defined outflow.
4. We specify characteristics of altimetry and objects, which should be taken into account by the calculation and we enter required parameters distribution. For every segment, the terrain sector is automatically selected, where the liquid will spread.

Tab. 1 Values of biotopes and their environment providing for organisms, ecosystems annual services, ecosystems capital values and official price of territory in the Czech Republic in CZK.m⁻² (Chytrý et al., 2001)

Corine LC classes	Points	Biotopes value (BVM)	Ecosys. annual services value	Ecosystems value	Official prices Regul. of MFČR	Note
	Average	CZK.m ⁻²	CZK.m ⁻²	CZK.m ⁻²	CZK.m ⁻²	
1.1.1. Consistent urban development	0 - 2,4	0 - 30	669	13380	35 - 2250	By size of munic.
1.1.2. Inconsistent urban development	10,2	126	1946	38920	35 - 2250	By size of munic.
1.2.1. Industry and business centres	0 - 2,9	0 - 33	797	15940	35 - 2250	By size of munic.
1.2.2. Road and railway network with its surroundings	8,2	100	1445	28900	35 - 2250	By size of munic.
1.2.3. Ports	8,3	98	1747	34940	35 - 2250	By size of munic.
1.2.4. Airports	11,9	148	1989	39780	35 - 2250	By size of munic.
1.3.1. Areas of present mining of materials	13,4	166	1080	21600	35 - 2250	By size of munic.
1.3.2. Heaps and landfills	7,9	97	2476	49520	1	
1.3.3. Construction site	7,1	88	1055	21100	35 - 2250	By size of munic.
1.4.1. Urban green areas	19,3	238	2659	53180	35 - 820	By size of munic.
1.4.2. Sport and recreation areas	18,8	232	1986	39720	1 - 10	
2.1.1. Unirrigated arable land	11,2	138	1552	31040	2 - 10	By districts
2.2.1. Vineyards	15,2	188	2211	44220	42	
2.2.2. Orchards, hop-gardens, plantations	14,2	175	2205	44100	42	
2.3.1. Meadows and pastures	20,8	257	2562	51240	1 - 5	By districts
2.4.2. Mixture of fields, meadows and permanent crops	14,1	174	2120	42400	1 - 10	By districts
2.4.3. Agricultural areas with natural vegetation	21,5	266	2495	49900	1 - 5	By districts
3.1.1. Greenwoods	40,7	503	3898	77960	30	
3.1.2. Coniferous forests	26,2	324	3112	62240	22	
3.1.3. Mixed forests	28,5	352	3270	65400	26	
3.2.1. Natural pastures	33,0	408	2721	54420	3	
3.2.2. Steps and scrubs	53,0	655	3220	64400	1	
3.2.4. Transitions stages of forest and scrubs	23,5	291	2660	53200	1	
3.3.2. Rocks	39,8	492	2680	53600	1	
4.1.1. Wetlands and marches	33,5	414	3968	79360	1	
4.1.2. Peat bogs	53,3	659	4201	84020	1	
5.1.1. Watercourses	23,1	286	3470	69400	7	
5.1.2. Water surface	18,7	231	3702	74040	7	

5. Stochastic calculation of liquid spreading with random selection of parameters of altimetry, planimetry and liquid movement characteristics then follows. On figure 4, the relevant window is marked with the note „1000 x Monte Carlo“. The number of variants can be selected randomly; it may be more or less than 1000. The result of this calculation is a probability field of single points affection by outflow in every single segment. If we multiply these probabilities by modified accident frequency, we get the field of points affection frequencies, which are influenced by outflow in given segment.

$$F(x, y) = \sum_S F_S \cdot P(x, y)_S \quad (2)$$

where $F(x, y)$ is point affection frequency, F_S accident frequency in s -th route segment, modified according to local conditions, $P(x, y)_S$ point $[x, y]$ affection probability by accident in s -th segment.

6. To every point, we assign the biotope, which occurs there, and then we determine the reduction of its value per 1 m².

7. We multiply the loss in single points by the frequency of their affection. The sum of loss in single points represents total ecologic loss along the traffic route.

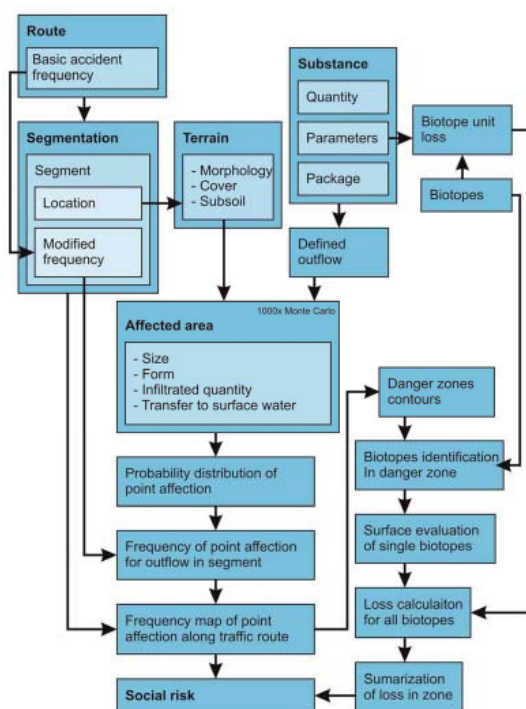


Fig. 4 Diagram of social risk assessment for biotopes

On Fig. 6, biotopes in the danger zone according to Natura 2000 BVM in the same area like on Fig. 5 are displayed. On the figure there are some large areas of incorrectly specified biotopes, marked like mosaic. Mosaic combines 2 or more different biotopes.

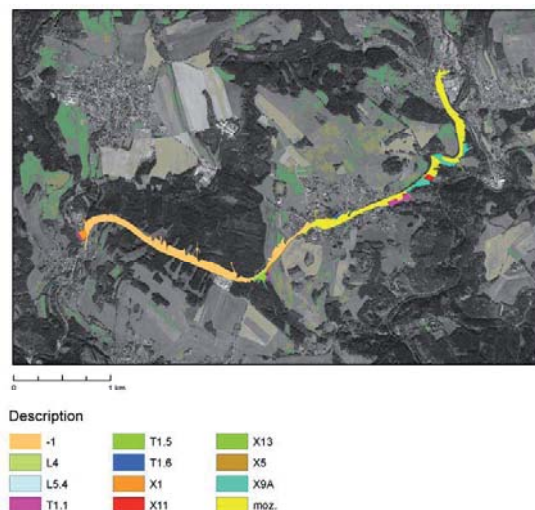


Fig. 6 Biotopes occurrence according to Natura BVM in danger zone of leaked diesel oil in the segment of the road E65 Loužnice - Plavy

Biotopes occurrence in danger zone

The demonstration of biotopes occurrence according to CORINE LC in danger zone of leaked liquid can be seen on Fig. 5. The base is the orthophotomap of the area.

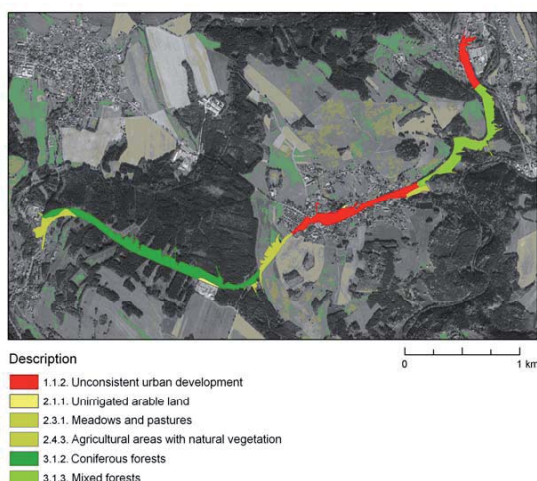


Fig. 5 Biotopes occurrence according to CORINE LC in danger zone of leaked diesel oil in the segment of the road E65 Loužnice - Plavy

Biotope valuation in danger zone

The list of biotopes, which occur in the danger zone of leaked liquid by transport of 30 m³ of diesel oil by the road E65 between Loužnice and Plavy, is summarized in Tab. 2. The annual point value, value of the degraded biotope after affection of leaked diesel oil and resulting unit loss are stated for all of them.

Conclusion

The exercise of liquid outflow is more difficult than for gases. Also the biotopes identification in the danger zone is more difficult than the assessment of population number from address points sets. Large complications come from data inconsistencies, which are not available for different areas. Detailed evaluation was done only for the segment of the road E65 between Loužnice and Plavy. Formulated procedures of identification will be necessary to verify also in different areas.

The valuation of biotopes in the danger zone along the road between Loužnice and Plavy was done with the usage of point and financial expression. The first attempt to risk calculation was done on the small road segment 400 meters long. Probabilities of point affection by leaked diesel oil in road closeness by

accident in random 10 m segment of the road were calculated. Still no accident frequency was counted. This frequency may be modified according to local conditions (crossroad, curve). After the accident frequency evaluation in single route segments, it will be possible to determine the frequency of point affection in the danger zone.

Acknowledgments

This research was supported by the Ministry of the environment of the Czech Republic, project No. TA01030833 - Integrated information system for road transportation of dangerous chemicals

Tab. 2 The list of biotopes in the threatened zone

BIOTOPE NATURA 2000	BVM		BVM default	Type of biotope after degradation	BVM degradation	Point loss
			Points		Points	Points/m ²
L2.2B	L2.2B	Valley ash-alder wetlands	42	XL3	20	22
L4	L4	Ravine forests	42	XL3	20	22
L5.4	L5.4	Acidophilous beech forests	38	XL3	20	18
S1.2	S1.2	Crevice vegetation of silicate rocks and of fall	46	XS1-2	12	34
T1.1	T1.1	Mesophilic tall oatgrass meadows	33	XT3	15	18
T1.5	T1.5	Wet thistle meadows	49	XT2	17	32
T1.6	T1.6	Wet meadowsweet fallow	46	XT2	17	29
X1	X5.2/XX3.1	Utility garden and gardening colonies / developed area with minimal vegetation	8,4	XX4.2	0	8,4
X12	XK2	Fallow with scrug vegetation and trees	24	X4.5	10	14
X13	XL1	Hedgerows, alleys and line trees vegetation in landscape	25	X4.5	10	15
X14	XV4	Locally modified watercourses	23	X1.4	6	17
X5	XT3	Intensive or degraded mesophilic meadows	13	X4.5	10	3
X6	XT6	New mining spaces and heaps of natural substrates	13	X4.7	6	7
X7	XT3	Intensive or degraded mesophilic meadows	13	X4.5	10	3
X11	XL5	Clearings, forest after planting and renaturalization planting	20	X4.5	10	10
X9A	XL4	Monocultures of habitat inappropriate timbers	20	X4.5	10	10

References

- Committee for the Prevention of Disasters (CPR), Directorate-General of Labour of the Ministry of Social Affairs. (2005). *Methods for the Calculation of Physical Effects Resulting from Releases of Hazardous Materials (Liquids and Gases), (Yellow Book)*, 3rd ed., The Hague, 2005, CPR 14E.
- CROWL, D. A., LOUVAR, J. F. (1990). *Chemical Process Safety: Fundamentals with Application*, PTR Prentice-Hall Inc., A. Simon & Schuster Company, Englewood Cliffs, New Jersey, 1990.
- CHUDOVÁ, D., BLAŽKOVÁ, K. (2007). *Přepřava nebezpečných látek z pohledu havarijního plánování území. Sborník vědeckých prací Vysoké školy báňské - Technické univerzity Ostrava, Řada bezpečnostního inženýrství*, 2007, ročník LIII, č. 1. ISSN 1801-1764. (in Czech)
- CHYTRÝ, M., KUČERA, T., KOČÍ, M. (2001). *Katalog biotopů České republiky*. Praha: Nature Conservation Agency of the Czech Republic, 2001. 307 s. ISBN 80 -86064 -55 -7 (in Czech).
- KONTULA, T., RAUNIO, A. (2009). New method and criteria for national assessments of threatened habitat types. *Biodiversity and Conservation*. 2009, Volume 18, Issue 14, p. 3861 - 3876. ISSN 09603115.

- SASKA, T., NOVÁK, J., ŠMÍDA, J., HAVLÍČEK, J., SOUŠEK, R. (2010). GIS software tools application for dangerous goods transport risk evaluation. In: *Proceedings of the Reliability, Risk and Safety - "ESREL"*. Rhodes, 2010. ISBN 978-0-415-60427-7.
- SEJÁK, J., DEJMAL, I., et al. (2003). *Hodnocení a oceňování biotopů České republiky*. Praha: Czech Ecologic Institute, 2003. 422 p. ISBN 80-85087-54-5 (in Czech).
- SEJÁK, J., et al. (2010): *Hodnocení funkcí a služeb ekosystémů České republiky*. Ústí nad Labem: Faculty of environment, J.E.Purkyně University in Ústí nad Labem, 2010. 197 s. ISBN 978-80-7414-235-2 (in Czech).
- SIMMONS, C. S., KELLER, J. M. (2003). Status of Models for Land Surface Spills of Nonaqueous Liquids [online]. Pacific Northwest National Laboratory, Richland, 2003. Available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-14350.pdf.
- SIMMONS, C. S., KELLER, J. M. (2005). The Influence of Selected Liquid and Soil Properties on the Propagation of Spills Over Flat Permeable Surfaces [online]. Pacific Northwest National Laboratory, Richland, 2005. Available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-15058.pdf.